(NASA-CR-184367) ECLSS EVOLUTION: ADVANCED INSTRUMENTATION INTERFACE REQUIREMENTS. VOLUME 3: APPENDIX C (Spectra Research Systems) 60 p

N93-12950

Unclas

G3/54 0121104

SRS/STG-TR92-01

Volume III - Appendix C
Task 3 Report
ECLSS Evolution: Advanced Insrumentation Interface Requirements

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

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Task 3 - ECLSS Evolution: Advanced Technologies Interface Requirements

The clarified statement of work for this task was understood as follows. Building on the Environmental Control and Life Support System (ECLSS) technologies database initiated by MacDonnell Douglas Space Systems Company (MDSSC), for each ECLSS technology, identify and describe the required interfaces including: fluid interfaces (flow rates, composition, temperature, pressure, etc.); electrical interfaces (average and minimum/maximum power levels, number of power lines, etc.); data/control interfaces (number of data/control lines, likely data rates, etc.; resupply (types of expendables including filters, reactors, etc. and the quantities).

An Advanced ECLSS Technology Interfaces Database was developed primarily to provide ECLSS analysts with a centralized and portable source of ECLSS Technologies interface requirements data. In addition to studying interface issues, this database provides data to the resupply analysis task and the "Hooks and Scars" study and Cost/Benefit analysis task. The database contains 20 technologies which were previously identified in the MDSSC ECLSS Technologies database. The primary interfaces of interest in this database are fluid, electrical, data/control interfaces, and resupply requirements. Each record contains fields describing the function and operation of the technology. Fields include: an interface diagram, a description, applicable design points and operating ranges, and an explaination of data, as required. A complete set of data was entered for six of the twenty components including Solid Amine Water Desorbed (SAWD), Thermoelectric Integrated Membrane Evaporation System (TIMES), Electrochemical Carbon Dioxide Concentrator (EDC), Solid Polymer Electrolysis (SPE), Static Feed Electrolysis (SFE), and BOSCH. Data for these 6 components has come from the ECLSS Technology Demonstrator Hardware (alias Technology Demonstration Program (TDP)) data books, primariliy the Interface Control Documents (ICD). Additional data was collected for Reverse Osmosis Water Reclaimation - Potable (ROWRP), Reverse Osmosis Water Reclaimation - Hygiene (ROWRH), Static Feed Solid Polymer Electrolyte (SFSPE), Trace Contaminant Control System (TCCS), and Multifiltration Water Reclaimation - Hygiene (MFWRH). A summary of database contents is presented in Exhibit C-1. Database printouts of the six completed data records are presented in Appendix E. With the database structure and report forms already developed, and pending the avilablility of data, the remaining data should be entered. The database is resident on the Macintosh computer with Foxbase+/Mac as the host software. Copies of the database have been delivered to NASA.

ECLSS Technologies
Interface Data

ECLSS Subsystem	Function	Technologies	Baseline ECLSS Technology	Interfaces Data Collected	Data in Interfaces Database
AR	CO_2 Removal	4-Bed Molecular Mole Sieve (4BMS)	✓		
		2-Bed Molecular Mole Sieve (2BMS)			
		Lithium Hydroxide Canisters (LIOH)			
		Solid Amine Water Desorbed (SAWD)		✓	✓
		Electrochemical Depolarized CO 2 Concentrator (EDC)		✓	✓
		Air Polarized CO_2 Concentrator (APC or EDC W/WO H_2)			
	CO_2 Reduction	Bosch		✓	✓
		Sabatier	✓		
		Advanced Carbon Reactor (ACR)			
	O_2 Generation	Static Feed Water Electrolysis (SFWE)	✓	✓	✓
		Solid Polymer Electrolysis - Liquid Anode Feed (SPE)		✓	✓
		Water Vapor Electrolysis (WVE)			
		Static Feed Solid Polymer Electrolyte (SFSPE)		✓	
	O_2 Generation/CO_2 Reduction	CO_2 Electrolysis			
	Airborne Contaminent Control	Trace Contaminent Control System (TCCS)		✓	
WRM	Urine Recovery	Thermoelectric Integrated Membrane Evaporation Subsystem (TIMES)		✓	✓
		Vapor Compression Distillation (VCD)	✓		
	Water Processing	Air Evaporation System (AES)			
		Vapor Phase Catalytic Ammonia Removal (VPCAR)			
		Reverse Osmosis (RO) *		✓	
		Multifiltration (MF) *	✓	✓	
		Electrodeionization			

* Data has been collected for ROWR-Potable, ROWR- Hygiene, and MFWR-Hygiene

Exhibit C-1. Summary of Interface Database Contents

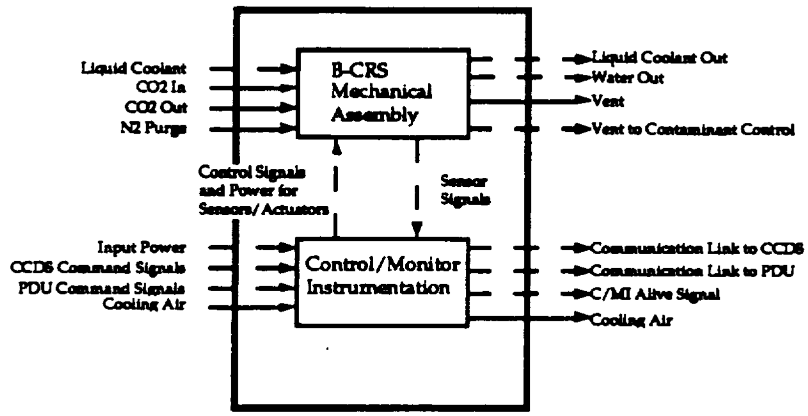
The gathering of technologies interfaces data was actively pursed but the applicable data is scarce. For the six entries in the interfaces database, we were able to locate lists of the ORU's but no real resupply data such as weights, rates, volumes, Mean Time to Repair (MTTR) and Mean time Between Failure (MTBF), was located.

Appendix C-1
Printout of the Interfaces Database

Advanced ECLSS Technologies Interfaces Database

Component name: BOSCH

BOSCH III Process Interfaces Block Diagram



B-CRS Subsystem Interface

Type:	Description, units	Design Pt	Min	Max	Other
Metabolic CO2					
	Flow Rate, lb/day	8.80	8.80	17.60	
	Temperature, F	70.00	60.00	85.00	
	Pressure, psia	18.00	14.70	20.00	
H2 Feed					
	Flow Rate, lb/day	0.80	0.80	1.60	
	Temperature, F	75.00	75.00	100.00	

Component name: BOSCH

Pressure, psia	30.00	14.70	30.00	
Product Water				
Flow Rate, lb/day	7.20	7.20	14.40	
Temperature, F	60.00	60.00	90.00	
Pressure, psia	30.00	14.70	30.00	
Coolant (Water)				
Flow Rate (lb/hr)	300.00	300.00	300.00	
Temperature (In/Out), F	—	—	—	Design Point:In-42, Out-44; Range: In-42, Out-46
Pressure, psia	30.00	30.00	30.00	
Bleed (a)				
Flow Rate, lb/day	1.12	1.12	1.12	(a) Applies to contaminated reactant feed gases

Advanced ECLSS Technologies Interfaces Database

Component name: BOSCH

Temperature, F	75.00	65.00	90.00
Pressure, psig	18.00	14.70	20.00
Carbon Canister			
Contents, lb	36.00	—	—
Changeout Interval, days	15.00	7.50	15.00
Electric Power			
28 VDC, W	341.00	306.00	606.00
115 AC, W	186.00	170.00	3120.00
Heat Rejection, W			
To Air	529.00	494.00	818.00
To Coolant	238.00	181.00	461.00

CCDS Communication Link

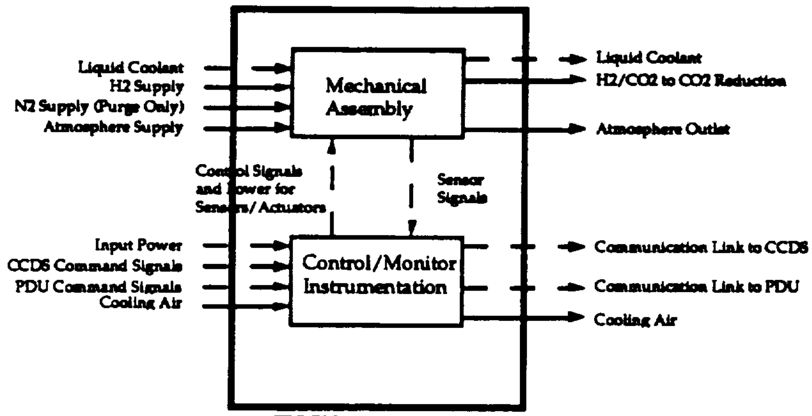
Component name: BOSCH

CCDS Communication Link	—	—	—	Design Point- RS-232C

Advanced ECLSS Technologies Interfaces Database

Component name: ELECTROCHEMICAL DEPOLARIZED CO2 CONCENTRATOR (EDC)

EDC-IV Process Interfaces Block Diagram



EDC-IV Subsystem Interface

Type:	Description, units	Design Pt	Min	Max	Other
Conditioned Atmosphere					
	Rate, ACFM	54.00	—	—	
	Temperature, F	70.00	60.00	85.00	
	Dew Point, F	50.00	35.00	70.00	
	Pressure, in H2O	—	—	—	
	pCO2, mmHG	2.70	—	12.00	
H2 Supply					

Component name: ELECTROCHEMICAL DEPOLARIZED CO2 CONCENTRATOR (EDC)

Rate, lb/day	1.39	—	1.89	
Pressure, psig	15.00	15.00	18.00	
Dew Point, F	50.00	40.00	65.00	
N2 Supply				
Rate, slpm	6.00	—	—	
Pressure, psig	15.00	—	—	
Liquid Coolant				
Fluid	—	—	—	Design Point- Water; Range- 50% Ethylene Glycol
Rate, lb/hr	1600.00	1600.00	2500.00	
Temperature, F	40.00	40.00	46.00	
H2/CO2 Outlet				

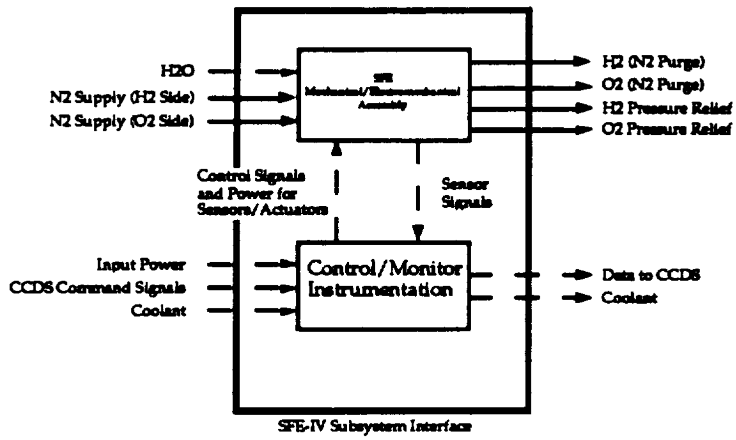
Component name: ELECTROCHEMICAL DEPOLARIZED CO2 CONCENTRATOR (EDC)

Rate, lb/hr	9.90	—	18.90	
H2/CO2 Exhaust				
Pressure, psig	3.00	—	5.00	
Electric Power				
DC, W (28V)	192.00	—	—	
Total Heat Rejection				
Total Heat Rejection	524.00	—	—	Range - <839
CCDS Communication Link				
CCDS Communication Link	—	—	—	Design Point - RS232

Advanced ECLSS Technologies Interfaces Database

Component name: STATIC FEED WATER ELECTROLYSIS (SFWE)

SFE-IV Process Interfaces Block Diagram



Type:	Description, units	Design Pt	Min	Max	Other
Product O2					
	Pressure, psia	20.00	14.50	25.00	
	Temperature, F	70.00	60.00	85.00	
	Dew Point, F	54.00	40.00	65.00	
	Water Vapor, lb/day	0.09	—	0.12	
Product H2					
	Rate, lb/day	1.39	—	1.84	

Component name: STATIC FEED WATER ELECTROLYSIS (SFWE)

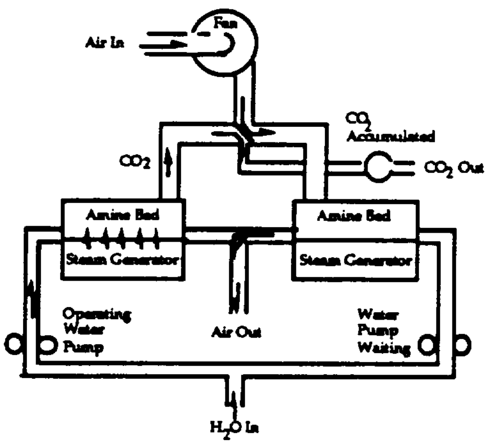
Pressure, psia	20.00	14.50	25.00	
Temperature, F	70.00	60.00	85.00	
Dew Point, F	54.00	40.00	65.00	
Water Vapor, lb/day	0.18	—	0.23	
Water Feed				
Rate, lb/day	12.78	—	16.92	
Pressure, psia	30.00	30.00	35.00	
Temperature, F	70.00	60.00	85.00	
Quality	—	—	—	Design Point-Potable or Hygiene; Range-Potable or Hygiene
N2 Supply (O2 Side)				

Component name: STATIC FEED WATER ELECTROLYSIS (SFWE)

Rate, lb/day	0.08	—	1.00	
Pressure, psia	182.00	180.00	185.00	
N2 Supply (H2 Side)				
Rate, lb/day	—	—	1.00	
Pressure, psia	182.00	180.00	185.00	
Electric Power				
DC, W (28V)	96.00	—	96.00	
DC, W (40V Nominal)	1162.00	—	1580.00	
Total Heat Rejection, W				
Total Heat Rejection, W	216.00	—	220.00	
CCDS Communication Link				
CCDS Communication Link	—	—	—	Design Point-RS232, Range-RS232

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID AMINE WATER DESORBED (SAWD)



The Fundamental SAWD Process

Type:	Description, units	Design Pt	Min	Max	Other
		—	—	—	
Fluid - Inlet Process Air					
	Flow Range, CFM	—	—	25.00	
	Pressure Range, IWG	—	—	-1.00	
	Temperature Range, deg F	—	40.00	50.00	
	Purity (in terms of the partial pressure of CO2 and the relative humidity)	—	—	—	CO2, 0-11 mm Hg, RH 90-100%

Component name: SOLID AMINE WATER DESORBED (SAWD)

Fitting/Line	—	—	—	Fitting: Size-2.0", Material-321SS, Type-V Band clamp style, MFGR-Aeroequip; Line: Size 2.0, Material-316SS
Fluid - Outlet Process Air				
Flow Range, CFM	—	—	25.00	
Pressure Range, IWG	—	—	1.00	
Temperature Range, deg F	—	—	—	55 - 110 deg F Maxium Average;165 deg F Maximum Instantaneous
Purity (in terms of the partial pressure of CO2 and the relative humidity)	—	—	—	CO2, 0-11 mm Hg, RH 90-100%
Fitting/Line	—	—	—	Fitting: Size-2.0", Material-321SS, Type-V Band clamp style, MFGR-Aeroequip; Line: Size 2.0, Material-316SS
Fluid - Hygiene H2O				

Component name: SOLID AMINE WATER DESORBED (SAWD)

Flow Range, PPH	—	—	5.00	
Pressure Range, PSIG	—	—	10.00	
Temperature Range, deg F	—	55.00	100.00	
Purity	—	—	—	Conductivity <10 micromhos/cm
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-321SS, Type-compression, MFGR-Crawford Fitting Co. (Swagelock); Line: Size 1/4", Material-316SS
Fluid - Vent				
Flow Range, PPH	1.10	—	—	
Pressure Range, PSIA	—	—	—	Ambient to 19.0

Component name: SOLID AMINE WATER DESORBED (SAWD)

Temperature Range, deg F	—	55.00	85.00	
Purity	—	—	—	1% Air, RH 100%
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-321SS, Type-compression, MFGR-Crawford Fitting Co. (Swagelock); Line: Size 1/4", Material-316SS

Fluid - CO2 Outlet

Flow Range, PPH	1.10	—	—	
Pressure Range, PSIA	—	—	—	Ambient to 19.0
Temperature Range, deg F	—	55.00	85.00	
Purity	—	—	—	1% Air, RH 100%

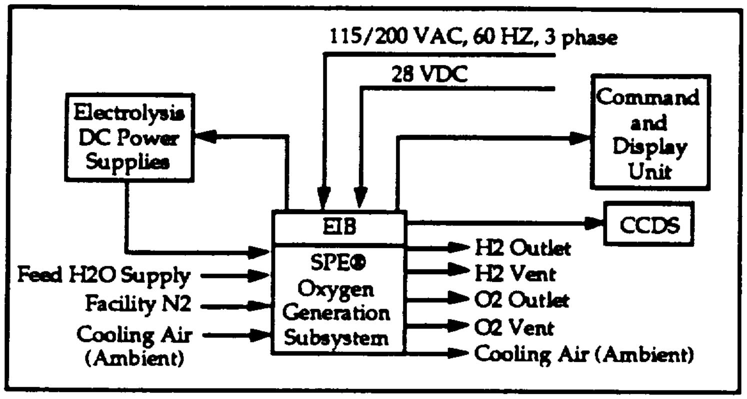
Component name: SOLID AMINE WATER DESORBED (SAWD)

Fitting/Line	—	—	—	Fitting: Size-1/4", Material-321SS, Type-compression, MFGR-Crawford Fitting Co. (Swagelock); Line: Size 1/4", Material-316SS
Instrumentation				
	—	—	—	There are no external instrumentation interfaces for the SAWD subsystem. All data will be provided via the RS232C port.

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

SPE Oxygen Generation Subsystem Block Diagram



Type:	Description, units	Design Pt	Min	Max	Other
		—	—	—	
Fluid - Feed H_2O Supply					
	Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O_2 Outlet					
	Fitting/Line	—	—	—	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H_2 Outlet					

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Facility N2				
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O2 Vent				
Fitting/Line	—	—	—	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H2 Vent				
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Cooling Air In				

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
Fluid - Cooling Air Out				
Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
Fluid - Feed H2O Supply				
Flow, LB/HR	0.52	0.01	0.69	
Pressure, PSIA	35.00	25.00	45.00	
Temperature, deg F	—	60.00	120.00	The nominal or design point is Ambient Temperature.
Purity	—	—	—	Per MMC-ECLSS-2
Fluid - O2 Outlet				
Flow, LB/HR	0.46	0.01	0.61	

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Pressure, PSIA	20.00	—	230.00	Minimum pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient.
Purity	—	—	—	>99.95% O2; see ICD for footnote
Fluid - H2 Outlet				
Flow, LB/HR	0.06	—	0.08	
Pressure, PSIA	25.00	—	195.00	Minimum pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient.
Purity	—	—	—	>99.95% H2; see ICD for footnote
Fluid - Facility N2				

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Flow, in^3 at start-up	67.00	67.00	67.00	
Pressure, PSIA	265.00	260.00	270.00	
Temperature, deg F	—	—	100.00	Minimum and nominal temperatures are ambient
Purity	—	—	—	High purity (99.99% N2)
Fluid - O2 Vent				
Flow, in^3 during ASD	8.50	8.50	8.50	
Pressure, PSIA	—	—	230.00	Minimum and Nominal Pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient

Purity	—	—	—	see ICD for footnote
Fluid - H2 Vent				
Flow, in^3 during ASD	73.00	73.00	73.00	
Pressure, PSIA	—	—	195.00	Minimum and Nominal Pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient
Purity	—	—	—	see ICD for footnote
Fluid - Cooling Air In				
Flow, CFM	85.00	85.00	85.00	
Pressure, PSIA	—	—	—	All Pressures are ambient

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Temperature, deg F	—	—	—	Nominal temperature is ambient
Purity	—	—	—	Cabin Air
Fluid - Cooling Air Out				
Flow, CFM	85.00	85.00	85.00	
Pressure, PSIA	—	—	—	All Pressures are ambient
Temperature, deg F	—	—	—	Nominal temperature is ambient
Purity	—	—	—	Cabin Air

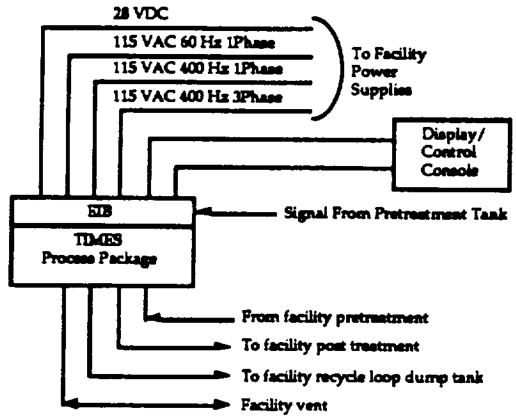
Electrical - Instrumentation

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

	—	—	—	There are no external instrumentation interfaces for the SPE Oxygen Generation Subsystem. All data will be provided via the RS232C port
Electrical - Cabling and Connectors				
	—	—	—	see ICD
Electrical - Data Bus Interface				
	—	—	—	see ICD
Electrical - Facility Power				
	—	—	—	see ICD

Advanced ECLSS Technologies Interfaces Database

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION SUBSYSTEM (TIMES)



TIMES Block Diagram

Type:	Description, units	Design Pt	Min	Max	Other
Fluid - Inlet Waste Water					
	Flow Rate, LBM/HR	3.90	2.40	5.00	
	Pressure, PSIA	20.00	15.00	25.00	
Fluid - Product Water					
	Flow Rate, LBM/HR	3.50	2.20	4.50	
	Pressure, PSIA	15.00	15.00	19.00	
Fluid - Inlet Waste Water					

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION SUBSYSTEM (TIMES)

Fitting/Line	—	—	—	Fiting: Size-3/8", Material-Titanium, Type-Bulkhead Union -600-61, MFGR.-SWAGLOK / Line: Size-3/8" Tube, Material-Titanium
Temperature, deg F	—	65.00	165.00	
Fluid - Product Water				
Fitting/Line	—	—	—	Fiting: Size-3/8", Material-Titanium, Type-Bulkhead Union -600-61, MFGR.-SWAGLOK / Line: Size-3/8" Tube, Material-Titanium
Temperature, deg F	—	75.00	95.00	
Fluid - Vent Gases				
Flow Rate, LBM/HR	0.01	—	0.10	
Pressure, PSIA	15.00	2.00	15.00	

Advanced ECLSS Technologies Interfaces Database

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION SUBSYSTEM (TIMES)

Fitting/Line	—	—	—	Fitting: Size-1/4", Material-Titanium, Type-Bulkhead Union -600-61, MFGR-SWAGELOK TUBE / Line: Size-1/4", Material-Titanium
Temperature, deg F	—	75.00	90.00	
Fluid - Outlet Brine Water				
Flow Rate, LBM/HR	550.00	500.00	600.00	
Pressure, PSIA	20.00	15.00	25.00	
Fitting/Line	—	—	—	Fitting: Size-3/8", Material-Titanium, Type-Bulkhead Union -600-61, MFGR-SWAGELOK / Line: Size-3/8" Tube, Material-Titanium
Fluid - Cooling Air				
Pressure, PSIA	—	—	—	Ambient

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION SUBSYSTEM (TIMES)

Temperature, Deg F	70.00	—	—	
Fluid - Pressure Equilization Air				
Flow Rate, CFM	1.30	1.30	1.30	
Pressure, PSIA	—	—	—	Ambient
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-Titanium, Type-Bulkhead Union -600-61, MFGR-SWAGELOK / Line: Size-1/4" Tube, Material-Titanium
Temperature, Deg F	70.00	—	—	
Electrical - Instrumentation				
Number: J308 Weight Sensor, Type: KJSE8N35SN,Mating Connector: KJ6F8N35PN, MFGR: ITT Cannon	—	—	—	Pin 1, Signal +, 0-5VDC = 0-100LBS (+/- 0.02LBS); Pin 2, Signal -; Pin 3, Case; Pin 4, shield; Pin 5 & Pin 6 Unused
Electrical - Cabling and Connectors				

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION SUBSYSTEM (TIMES)

Number: J101 Primary 60 Hz Power, Type: KJ5E14N5PN,Mating Connector: KJ6F14N5SNN, MFGR: ITT Cannon	—	—	—	Pin A, 115 VAC, 60 Hz, Phase A; Pin B, 115 VAC, 60 Hz, Phase B, not used; Pin C; 115VAC, 60 Hz,Phase C, not used, Pin D, Neutral, Pin E, Safety Ground
Number: J102 Primary 400 Hz Power, Type: KJ5E14N5PA,Mating Connector: KJ6F14N5SA, MFGR: ITT Cannon	—	—	—	Pin A-115 VAC,400 Hz, Phase A; Pin B-115 VAC,400 Hz, Phase B, not used; Pin C-115VAC,400 Hz,Phase C, not used; Pin D-Neutral; Pin E-Safety Ground
Number: J201 CCDS Interface, Type: KJ53E10N35SN,Mating Connector: KJ6F10N35PN, MFGR: ITT Cannon	—	—	—	

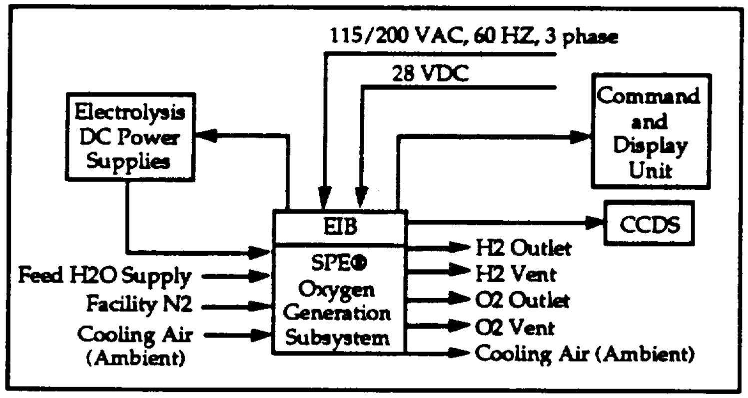
Electrical - Data Bus Interface

	—	—	—	There will be 8 data packets utilized by HSD hardware in Tech Demo.

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

SPE Oxygen Generation Subsystem Block Diagram



Type:	Description, units	Design Pt	Min	Max	Other
		—	—	—	
Fluid - Feed H2O Supply					
	Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O2 Outlet					
	Fitting/Line	—	—	—	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H2 Outlet					

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Facility N2				
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O2 Vent				
Fitting/Line	—	—	—	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H2 Vent				
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Cooling Air In				

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
Fluid - Cooling Air Out				
Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
Fluid - Feed H2O Supply				
Flow, LB/HR	0.52	0.01	0.69	
Pressure, PSIA	35.00	25.00	45.00	
Temperature, deg F	—	60.00	120.00	The nominal or design point is Ambient Temperature.
Purity	—	—	—	Per MMC-ECLSS-2
Fluid - O2 Outlet				
Flow, LB/HR	0.46	0.01	0.61	

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Pressure, PSIA	20.00	—	230.00	Minimum pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient.
Purity	—	—	—	>99.95% O2; see ICD for footnote
Fluid - H2 Outlet				
Flow, LB/HR	0.06	—	0.08	
Pressure, PSIA	25.00	—	195.00	Minimum pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient.
Purity	—	—	—	>99.95% H2; see ICD for footnote
Fluid - Facility N2				

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Flow, in^3 at start-up	67.00	67.00	67.00	
Pressure, PSIA	265.00	260.00	270.00	
Temperature, deg F	—	—	100.00	Minimum and nominal temperatures are ambient
Purity	—	—	—	High purity (99.99% N2)
Fluid - O2 Vent				
Flow, in^3 during ASD	8.50	8.50	8.50	
Pressure, PSIA	—	—	230.00	Minimum and Nominal Pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient

Purity	—	—	—	see ICD for footnote
Fluid - H2 Vent				
Flow, in^3 during ASD	73.00	73.00	73.00	
Pressure, PSIA	—	—	195.00	Minimum and Nominal Pressure is ambient
Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient
Purity	—	—	—	see ICD for footnote
Fluid - Cooling Air In				
Flow, CFM	85.00	85.00	85.00	
Pressure, PSIA	—	—	—	All Pressures are ambient

Temperature, deg F	—	—	—	Nominal temperature is ambient
Purity	—	—	—	Cabin Air
Fluid - Cooling Air Out				
Flow, CFM	85.00	85.00	85.00	
Pressure, PSIA	—	—	—	All Pressures are ambient
Temperature, deg F	—	—	—	Nominal temperature is ambient
Purity	—	—	—	Cabin Air

Electrical - Instrumentation

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

	—	—	—	There are no external instrumentation interfaces for the SPE Oxygen Generation Subsystem. All data will be provided via the RS232C port
Electrical - Cabling and Connectors				
	—	—	—	see ICD
Electrical - Data Bus Interface				
	—	—	—	see ICD
Electrical - Facility Power				
	—	—	—	see ICD

SRS/STG-TR92-01

Volume III - Appendix D
Task 4 Report
ECLSS Evolution: Resupply Analysis

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

APPROVED BY: Jay H. Laue
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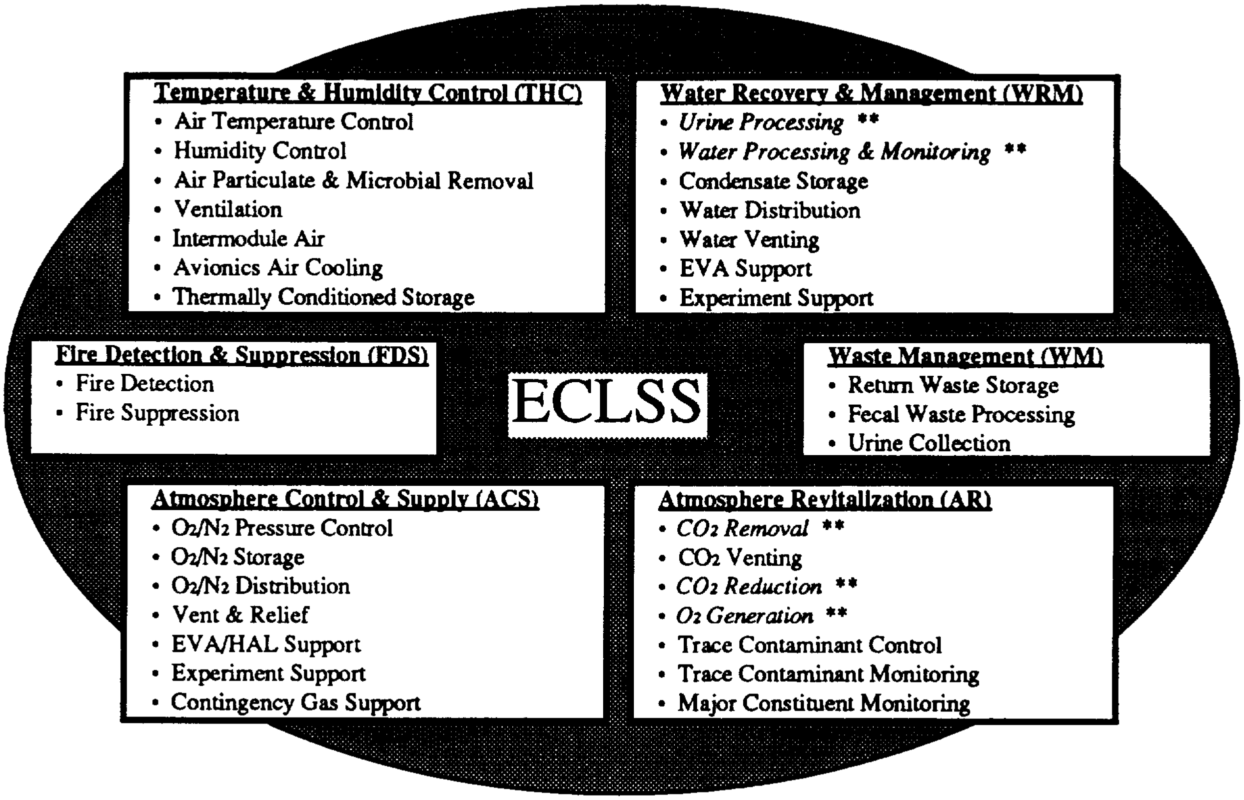
Task 4 - ECLSS Evolution: Resupply Analysis

Based on the resupply requirements for each technology identified in Task 2 (the ECLSS Evolution: Intermodule Ventilation Study), this task called for the estimation of the logistics requirements to support each technology including analyses for different phases of Space Station *Freedom* evolution in which there will be different crew sizes, considering the potential for "economies of scale." Also, methods of reducing logistics weight and volume were to be recommended.

The purpose of this task was to determine the logistics requirements to support each ECLSS technology described in the Technology Database developed by McDonnell Douglas Space Systems Company (MDSSC) and to analyze the logistics requirements, for each technology, for different phases of the Space Station Freedom evolution in which there will be different crew sizes. Due to the lack of required data and inconsistency in the data gathered the effort focused on development of guidelines and procedures for a more meaningful technologies logistics requirements analysis. In addition, some issues to consider for reducing logistics weight and volume were also determined.

The ECLSS for the EMCC Space Station Freedom (SSF) configuration consist of six functional areas, each having multiple subsystems, as shown in Exhibit 2.5.2-1. The technologies described in the database are limited to Atmosphere Revitalization (AR) and Water Recovery and Management (WRM). The subsystems described in the database are CO_2 removal, CO_2 reduction, O_2 generation, urine processing, and water processing, as shown in Exhibit D-1. Exhibit D-2 is a list of the technologies included in the database. This exhibit shows the functions of each technology and their related ECLSS subsystem.



** *Functional Areas Covered by the Technologies Database*

Exhibit D-1. SSF ECLSS for the EMCC Configuration

ECLSS Subsystem	Function	Technologies
AR	CO_2 Removal	4-Bed Molecular Mole Sieve (4BMS)
		2-Bed Molecular Mole Sieve (2BMS)
		Lithium Hydroxide Canisters (LIOH)
		Solid Amine Water Desorbed (SAWD)
		Electrochemical Depolarized CO_2 Concentrator (EDC)
		Air Polarized CO_2 Concentrator (APC or EDC W/WO H_2)
	CO_2 Reduction	Bosch
		Sabatier
		Advanced Carbon Reactor (ACR)
	O_2 Generation	Static Feed Water Electrolysis (SFWE)
		Solid Polymer Electrolysis - Liquid Anode Feed (SPE)
		Water Vapor Electrolysis (WVE)
	O_2 Generation/CO_2 Reduction	CO_2 Electrolysis
WRM	Urine Recovery	Thermoelectric Integrated Membrane Evaporation Subsystem (TIMES)
		Vapor Compression Distillation (VCD)
		Air Evaporation System (AES)
		Vapor Phase Catalytic Ammonia Removal (VPCAR)
	Water Processing	Reverse Osmosis (RO)
		Multifiltration (MF)
		Electrodeionization

Exhibit D-2. Technologies Included in the Technology Database

The related technologies can be better compared with each other by defining the logistics requirements, power penalty, heat rejection penalty, unit weight and volume, launch weight and volume, and operation life. Task 3 focused on defining the logistics requirements for each technology. However, due to a lack of detailed resupply information, the logistics requirements defined for the technologies are not sufficient to provide as meaningful analysis results as could be determined from a more comprehensive study. In order to develop meaningful logistics requirements and perform a more detailed logistics analysis and trade studies for each SSF evolution for each ECLSS technology, task 3 focused on the development of procedures for data collection, logistics analysis, and logistics trade studies, as described in the task flow shown in Exhibit D-3.

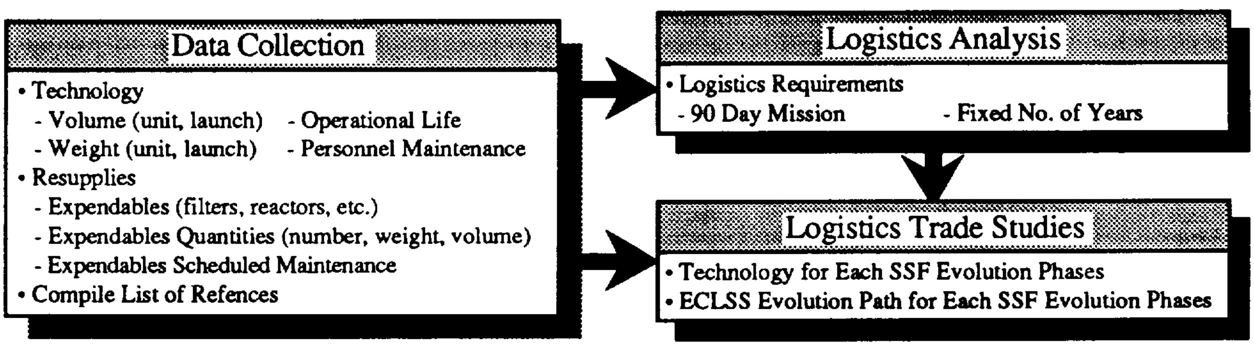


Exhibit D-3. Technologies Logistics Study Task Flow

Logistics requirements for each technology are based on resupply requirements and parameters that govern the transportation of the resupply items. The type of data to be collected can be broken down into categories, such as types of resupply expendables (filters, reactors, bottled gas, etc.), quantity of expendables, volume and weight (resupply, return, launch) of expendables, mean time between failures of expendables or operational life time, etc. In addition to these data categories, consideration should be given to the logistics involved with any special transportation environmental requirements (storage constraints - dimensions, temperature, power), special transportation packaging hardware, and personnel time required for maintenance. Exhibit D-4 shows a comparison of some of the higher level data collected for each of the technologies from two separate references. Due to inconsistencies in collected data, it was determined that 3 to 4 references should be used, if possible, to compare and verify the data collected. These inconsistencies can cause substantial error in the logistics analysis and trade studies. The information collected should then be summarized in a database to provide analysis capabilities in order to quickly perform logistics analysis and trade studies for the ECLSS technologies. Sources containing the required data for each technology should be compiled in a list for future reference and more detailed analysis.

ELCSS Technologies	Manrate (Person)		Weight (lb)						Volume (ft3)			
			Unit		90 Day				Unit		90 Day	
					Resupply		Return				Resupply	Return
	Ref 1	Ref 2	Ref 1	Ref 2	Ref 1	Ref 2	Ref 1	Ref 2	Ref 1	Ref 2	Ref 2	Ref 2
4BMS	4	8	246	425	- - -	0		0	14.0	33.1	0	0
2BMS	4		180		- - -				13.0			
LiOH	4		10		1176				2.0			
SAWD	4		228		3				14.0			
EDC	4		169		- - -				5.0			
APC	4		190		- - -				6.0			
Bosch	4	8	725	689	377	205		637	32.4	39.1	21.8	21.8
Sabatier	4	8	114	114	264	0		0	2.4	2.4	0	0
ACR	4		600		24				23.0			
SFWE	4	8	160	160	- - -	- - -		- - -	3.6	- - -	- - -	- - -
SPE	4		230		- - -				6.0			
WVE	4		119		- - -				3.0			
CO_2 Electrolysis	4		166		- - -				4.0			
TIMES	8	8	225	665	683	42		672	10.3	30.4	9.16	9.16
VCD	8		330		930				13.4			
AES	3		200		68				- - -			
VPCAR	8		300		800				18.0			
RO	8	8	566	1373	233	284		284	22.5	33.8	2.38	2.38
MF	8	8	160	1092	112	112		112	12.4	59.9	1.10	1.10
Electrodeionization	- -		30		- - -				2.0			

Reference 1 - "Advanced ECLSS Subsystem and Instrumentation Technology Study for the Space Exploration Initiative", McDonnell Douglas Space Systems Co., Contract NAS8-36407, October 1990.
Reference 2 - Pre-Turbo SSF ECLSS Data received from Paul Wieland, NASA-MSFC, November 1990.

Exhibit D-4. Some ECLSS Technologies Logistics Related Characteristics

Once sufficient data is collected, logistics requirements for each technology can be determined. This can be accomplished by using the resupply requirements, maintenance requirements, component operational life and operational capabilities data to calculate the logistics requirements for a given crew size and resupply period. By accounting for a technology's unit weight and volume, its operational life, and the major components' operational life, the technology's logistics requirements can be analyzed based on a set number of years. This would allow the related technologies to be compared based on total logistics requirements of transportation and maintenance for an extended length of time, such as the planned operational life time of the SSF. The technologies logistics data should then be summarized with a listing of any special transportation requirements that would require additional logistics.

From the information collected and the logistics requirements defined, various trade studies could be performed for better characterization and comparison of the related ECLSS technologies. These trade studies should include a study to determine the logistics requirements of the technologies based on each proposed SSF evolution configuration in which there will be different crew sizes. This study should involve defining the logistics requirements per 90-day resupply mission and total logistics requirements for a set number of years. Special consideration should be given to "economies of scale," such as reduction of total resupply logistics requirements per technology given an increase in the number of crews.

With the information developed from the resupply and logistics requirements study, an evaluation of the total logistics requirements for each SSF evolutionary configuration path could be conducted. An example task flow for this type of study is shown in Exhibit D-5. This study might include determining proposed ECLSS evolutionary paths (technology combinations and proposed technology upgrade or replacement) for each SSF evolutionary configuration path. The study should not include combinations of functionally related technologies, such as Bosch or Sabatier for CO_2 reduction, due to lack of commonality and increased logistics requirements. These trade studies would provide meaningful results that can be better used for determining the ECLSS configurations and evolution paths that minimize total ECLSS logistics requirements.

In order to reduce the logistics requirements for each technology (unit volume and weight, resupply requirements,etc.), consideration might be given to some of the issues shown in Exhibit D-6. The first two issues could be addressed through ventilation trade studies similar to the studies performed in task 1 of this contract. The later two issues would require detailed knowledge of the design, operations, and performance of each technology. Therefore, the later two issues might be better addressed by the developer of each ECLSS technology.

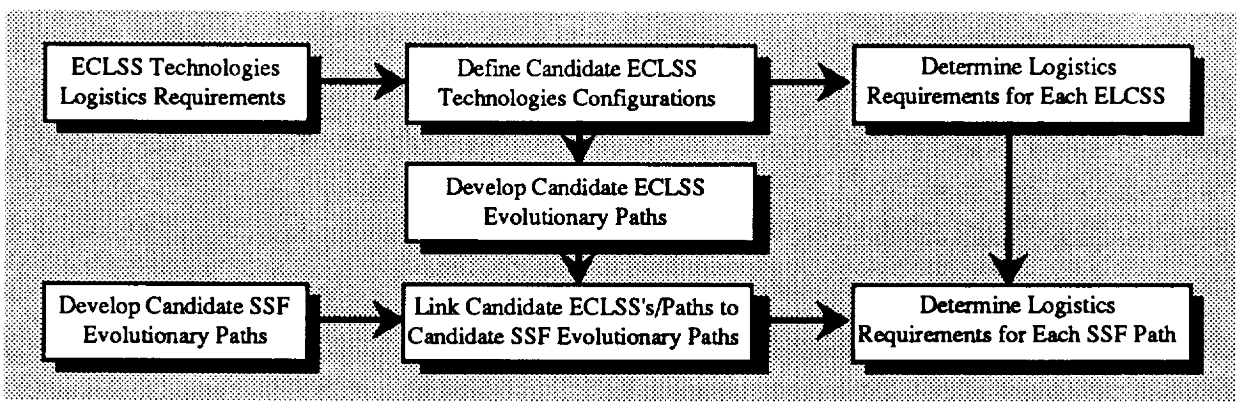


Exhibit D-5. Logistics Trade Study Task Flow for ECLSS Evolutionary Paths

1. Can the number of AR's required be reduced through improved ventilation and selection of optimum locations?

2. Should limitations be placed on the personnel concentration per area?

3. Can design modifications be made to improve performance?
   - Extended components operational life
   - Reduced weight and volume per unit or components
   - Increase man-rate limit to reduce the number of required units and resupplies

4. Can operations be simplified to reduce maintenance and resupply requirement?

Exhibit D-6. Logistics Requirement Reduction Issues

Results

The primary work accomplished under this task was a cursory evaluation of the ways to reduce logistics weight and volume. One recommendation from the cursory evaluation is to place the THCS for the logistics module in the node it attaches to. This would eliminate the need to repeatedly launch and return the THCS and would therefore allow more resupply mass and volume to be carried on the logistics module. A complete report is presented in Appendix D.

SRS/STG-TR92-01

Volume III - Appendix E
Task 5 Report
ECLSS Evolution: Module Addition/Relocation

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

APPROVED BY: Jay H. Laue
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Task 5 - ECLSS Evolution: Module Addition Relocation

The purpose of this task was to evaluate aspects other than ventilation as modules are added or relocated and as interior rearrangements are made. This task is an extension of the intermodule ventilation trade studies. Furthermore, this task involved development of ECLSS growth concepts consistent with SSF's growth phases and identified impacts such as additional interconnections required and other effects.

The following assessment identified studies recommended to insure that critical resources and ECLSS functional requirements are maintained during station configuration changes and evolutionary growth, including module addition and relocation, and that safe haven requirements are also met for each evolving configuration and during configuration changes. Examples of growth configurations that require analysis are described in Task 1 SSF Evolution Concepts Ventilation Trade Studies. Crew safety requirements are contained in SSP 30000 Section 3 Revision K. The following quote is from SSP 3000 Section 3 Revision K: "In general, station systems functions which are essential for crew safety and station survival shall be two failure tolerant as a minimum (except for primary structure and pressure vessels in the rupture mode). During initial station assembly and periods of maintenance these systems functions shall be single failure tolerant as a minimum and on-orbit restorable. Table 3-2.2 from SSP 30000 Section 3 Revision K, provides functional failure tolerance requirements. The space station shall provide the capability to isolate any element containing a catastrophically hazardous event from the remainder of the Space Station. In the event of any single failure, including the complete loss of one pressurized element, the space station shall provide safe haven capabilities to insure crew survival for a maximum duration of 22 days." Exhibit E-1 contains table 3.2-2 from SSP 30000 Section 3, revision K.

TABLE 3-2.2 SSMB FUNCTIONAL FAILURE TOLERANCE REQUIREMENTS

	FUNCTION		PRIME SUPPORTING SYSTEM[4]	CATEGORY	REQUIRED FAILURE TOLERANCE[1,2,3,7,8] MTC	PMC
1.0	Provide Safe & Healthy Working Environment					
	1.1	Respirable Atmosphere				
	1.1.1	O2 Generation/O2 Supply	BCLSS	1C	N/A	2
	1.1.2	O2/N2 Storage	BCLSS	1C	1	2
	1.1.3	O2/N2 Distribution	BCLSS	1C	1	2
	1.1.4	O2/N2 Pressure Control	BCLSS	1C	1	2
	1.1.5	CO2 Venting (PMC)/Reduction (AC)	BCLSS	1C	0	2
	1.1.6	CO2 Removal	BCLSS	1C	0	2
	1.1.7	Air Particulate & Microbial Control	BCLSS	1C	1	2
	1.1.8	Cabin Air Temperature and Humidity Control	BCLSS	1C	1	2
	1.1.9	Circulation	BCLSS	1C	1	2
	1.1.10	Vent & Relief	BCLSS	1C	1	2
	1.1.11	Atmosphere Composition Monitoring	BCLSS	1C	0	2
	1.1.12	Trace Contaminant Monitor	BCLSS	1C	N/A	2
	1.1.13	Trace Contaminant Control	ECLSS	1C	0	2
	1.2	Operational Lighting				
	1.2.1	General Lighting	Element Unique	2	1	1
	1.2.2	Task Lighting	Element Unique	3	0	0
	1.3	Acoustics				
	1.3.1	Hearing Conservation Acoustic Control	Element Unique	3	0	0
	1.3.2	Severe Discomfort Vibration Control	Element Unique	3	0	0
	1.4	Food				
	1.4.1	Food Storage	MS	1C	N/A	2
	1.4.2	Food Preparation	MS	2	N/A	1
	1.4.3	Food Waste Collection/Storage	MS	2	N/A	1
	1.5	Water (Potable/Hygiene)				
	1.5.1	Water Storage	ECLSS	1C	N/A	2
	1.5.2	Water Processing	ECLSS	1C	N/A	2
	1.5.3	Water Thermal Conditioning	MS	3	N/A	0
	1.5.4	Water Distribution	ECLSS	2	N/A	1
	1.6	Personal Hygiene				
	1.6.1	Reserved				
	1.6.2	Full Body Cleansing	MS	3	N/A	0
	1.6.3	Handwash/Partial Body Cleansing	MS	2	N/A	1
	1.6.4	Urine Collection	BCLSS	1C	N/A	2
	1.6.5	Urine Processing	BCLSS	2	N/A	1
	1.6.6	Urine Storage	ECLSS	1C	N/A	2
	1.6.7	Urine Removal	ECLSS	2	N/A	1
	1.6.8	Fecal Waste Collection	ECLSS	1C	N/A	2

[1]When present prior to PMC, the Space Shuttle may be considered as an additional path of redundancy to this table.
[2]Requirements apply from the primary stage listed up to, but not including, the next primary stage.
[3]In circumstances where a conflict exists between required failure tolerances, the most stringent requirement takes precedence.
[4]This column is intended to add clarity to the function descriptions. It is not a requirement nor a part of the functional partitioning.
[5]Failure tolerance for specific applications is achieved by superposition of these functional failure tolerance requirements with the safety failure tolerance requireme
[6]These functions shall be one failure tolerant at PMC minus one assembly flight.
[7]For PMC and following, crew survival functions may achieve two failure tolerance by using the ACRV in lieu of a redundant path.
[8]Those Category 1 functions that are shown to be time critical may be required to be 2 failure tolerant.

Exhibit E-1. Table 3-2.2 from SSP 30000 Section 3 Revision K

ECLSS functions recommended for assessment to meet redundancy and safe haven requirements for each evolving configuration including module addition and/or relocation (excluding intermodule ventilation) are as follows:

- O_2/N_2 storage and distribution
- Cabin air temperature and humidity control (including avionics air cooling)
- Trace contaminant control
- Water storage and processing and distribution
- Urine processing storage
- Fecal waste collection
- Food storage

A study approach overview applicable to each of the above ECLSS functions is shown in Exhibit E-2. In each case the ECLSS requirements from the applicable documents should be used to develop study groundrules and requirements. Once the requirements are understood and a specific configuration has been selected the assessments can be made by developing a subsystem model and applying the model to the specific configurations or constraints of interest. The results including issues and recommendations can be reported and documented as indicated in the Exhibit E-3.

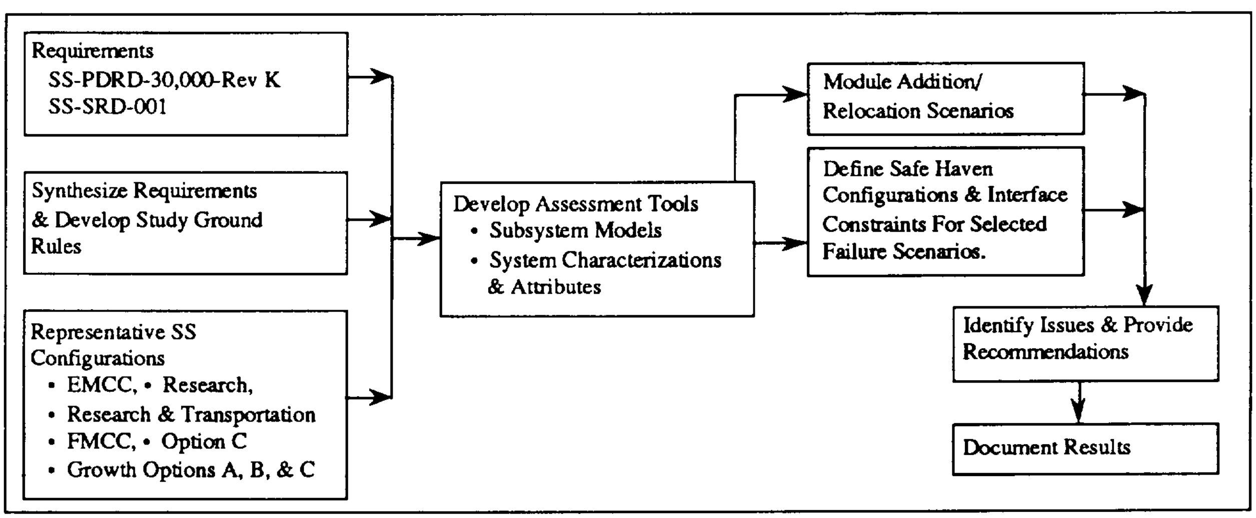

Exhibit E-2. Study Approach Overview

ECLSS Function	Recommended Study
O_2/N_2 Distribution	• Evaluate Space Station Build Up Scenarios • Evaluate Capability For Safe Haven Rqmts And Skipped Resupply • Identify Best Distribution Of Stored O_2/N_2 To Minimize Impacts Of Catastrophic System Loss
Cabin Air Temperature and Humidity Control	• Evaluate Function Distribution To Assure Safe Haven Reqmts Are Satisfied • Evaluate System Performance & Function Distribution To Assure That Space Station Growth Configurations & Build Up Scenario Requirements Can Be Satisfied • Evaluate System To Investigate Feasibility Of Removing Temperature & Humidity Control Equipment From Logistics Modules
Trace Contaminant Control	• Evaluate Trace Containment Control & Monitoring Capability For Configurations Build Up & Failure Scenarios Requiring A Safe Haven - Identify Distributions Of Monitoring And Control Equipment That Support Build Up And Safe Haven Requirements.
Water Storage, Processing, and Distribution	• Determine Adequacy Of Water Distribution System To Provide Redundant Paths To Accommodate Failure, Or Removal Of A Pressurized Module • Determine Capability To Accommodate Loss Of Processing Capability And Water Due To Loss Or Removal Of A Pressurized Modules
Fecal Waste Collection	• Assess Adequate Distribution Of Fecal Waste Collection Systems To Assume Safe Haven Requirements Can Be Met
Food Storage	• Assess Food & Equipment Distributions For Each Growth Configuration To Assure That Safe Haven Requirements Can Be Satisfied
System Study	• Combine The Results Of The Previous Studies And Other Information As Required To Define A Safe Haven Configuration For Each Growth Configuration And Failure Scenario

Exhibit E-3. Summary of Recommended Studies

O_2/N_2 Storage and Distribution

The PDRD 30000 Rev. K requires a Safe Haven for 22 days. A skip cycle or missed resupply requires 90 days of atmosphere gas. This includes 45 days of normal operation plus 45 days "safe mode" plus three, two person EVAs plus one hyperbaric treatment. A CR to revision K increases the crew survival requirements to 45 days, and provides for a delayed resupply of 90 days.

Based on atmosphere gas allocations (user requirements), resupply capabilities (cryo tankage storage capabilities and residuals, etc.), and the above requirements the capability of the system to meet the requirements can be assessed. From a brief review of the PDRD requirements there appears to be no requirements for distributing the stored gas such that a catastrophic event causing the loss of one storage system could be accommodated. In other words there is no backup gas storage system onboard the station. As the space station grows in crew and elements, a study objective could be to evaluate the benefits of distributing the gas storage to minimize the effects of losing one set of storage tanks, and to insure that safe haven and skip cycle requirements can be met for all growth configurations.

Cabin Air Temperature and Humidity Control

The temperature and humidity control system must be capable of meeting the safe haven requirements, and also have the flexibility to accommodate module additions and relocations.

These top level requirements and space station growth configuration characteristics will allow definition of thermal loads (crew and equipment and structural heat leak). A TRASYS/SINDA thermal model may be needed to evaluate the structural heat transfer, for the evolving configurations. A coolant loop model including the sensible and latent heat removal characteristics of the heat exchangers can be formulated to predict atmosphere temperatures and humidities for various build up scenarios and failure conditions.

These models can be used to assess the thermal control system capabilities for various configurations, failures, and build up scenarios. Study objectives would be to assess the configurations' build up scenario to determine that the thermal control system can meet temperature and humidity requirements; assess various failure scenarios and determine the optimum "safe haven" configuration for each failure case, and finally to evaluate for each configuration the need to provide heat exchanges in logistics modules. Fixed equipment weight and volume in the logistics modules is very expensive because it is launched repeatedly.

Trace Contaminant Control

Trace contaminants are controlled and monitored in the habitable environment. Short term maximum allowable concentrations, and continuous maximum allowable concentrations are specified. These requirements and the failure tolerance and safe haven requirements determine the trace contaminant control performance requirements for the various configurations and build-up scenario.

A system model similar to the intermodule ventilation model should be developed to assess the trace contaminant control system performance under various conditions. It may be desirable to add a transient capability to the model to evaluate recovery times for various failure scenarios. This capability would allow evaluation of the best distribution of control and monitoring equipment for each configuration and failure scenario. Study objectives would be to determine safe haven configurations for failure scenarios, and optimum locations of control and monitoring equipment to meet safe haven and build up scenarios.

Water Storage Processing and Distribution (Including Urine Collection Processing and Storage)

Failure tolerance requirements must be met for potable and hygiene water during space station configuration evolution. The system must also accommodate safe haven requirements. In the event a pressurized module is functionally lost due to removal or failure, the water distribution system must have redundant paths to provide resources to the remaining habitable volumes. The removal or loss of a module may involve water loss, and loss of water processing storage and recovery capability. The impacts of this loss can be assessed for each failure scenario, and/or configuration change.

The objectives of this study would be to determine the adequacy of the water distribution system to by pass disabled modules, and to provide sufficient reserve capability to accommodate water losses that could be associated with module losses. The study should also identify safe haven configurations for selected failure scenarios for each of the growth configurations.

Fecal Waste Collection

Each of the growth configuration failure scenarios involving the loss of pressurized modules will require identification of a safe haven configuration. The safe haven configuration should contain a fecal waste collection capability to support the entire crew. Assessments should be made to identify adequate distribution of fecal waste collection systems to assure that safe haven requirements are satisfied.

Food Storage

Safe haven provision requirements require food and equipment to be available in the remaining pressurized volume for a period of 22 days (SP 30000 Revision K), or 45 days (CR to Revision K).

An assessment to determine food and equipment distribution for each growth configuration should be made to assure these requirements are satisfied.

System Study

Shown in Exhibit 2.6.2-3 is a summary of study recommendations. The results from evaluating each subsystem should be combined with other requirements, such as access to escape vehicles, recovery of EVA personnel etc., to define a safe haven configuration for each of the growth station configurations. Although intermodule ventilation analysis was not performed under this task, the air distribution system characteristics and capabilities should be included in the overall system assessments to identify safe haven configurations and in investigating the buildup scenarios.

SRS/STG-TR92-01

Volume III - Appendix F
Task 6 Report
ECLSS Evolution: "Hooks and Scars" Study and Cost/Benefit Analysis

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

APPROVED BY: Jay H. Laue
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Task 6 - ECLSS Evolution: "Hooks and Scars" Study and Cost/Benefit Analysis

The purpose of task 6 was to identify the rack level interface requirements of the alternative technologies evaluated in Task 1 and compare these with the rack level interfaces for racks with the baseline technologies. Those technologies which require rack level interfaces not required by the baseline technologies were to be identified and the additional interfaces required were to be defined. Furthermore, the cost of implementing the identified "hooks and scars" including the costs of tubing, ducting, wiring, power, etc. were to be evaluated and compared with the benefits of reduced resupply, increased capabilities, simplified operation, reduced maintenance needs, etc. This effort is dependant on the availability of the results of the SSF restructuring activity to provide information on the baseline locations of ECLS subsystems, the interfaces provided, and the scars provided to accommodate EMCC.

The purpose of this task was to identify the rack-level interface requirements of the alternative technologies evaluated in Task 2 and compare these with the rack-level interfaces requirements for the baseline technologies. This involved identifying those technologies which require rack-level interfaces not required by the baseline technologies and defining the additional interfaces required. This effort was dependent on the availability of the results of the Space Station Freedom restructuring activity to provide information on the baseline locations of ECLSS subsystems, the interfaces provided, and the scars provided to accommodate the EMCC configuration. The analysis preformed under this tasked was focused on a specific Atmosphere Revitalization (AR) subsystem, O_2 Generation, in order to identify the rack-level interface "hooks and scars" requirements for the replacement of the EMCC baseline SFWE technology with the SPE technology.

In order to perform a comparative evaluation of the alternative ECLSS technologies rack-level requirements with the baseline technologies requirements, the baseline technologies were identified and are listed in Exhibit F-1. Based on the information gathered, the technologies represented in the Technology Interface Database (developed in Task 2), and given baseline technologies, the comparative analysis was conducted on the O_2 Generation AR subsystem. These O_2 generation subsystems include the baseline technology, Static Feed Water Electrolysis (SFWE), and an alternative replacement technology, Solid Polymer Electrolysis (SPE).

ECLSS Subsystem Category	Baseline Technology
CO2 Removal	4-Bed Molecular Mole Sieve (4BMS)
CO2 Reduction	Sabatier
O2 Generation	Static Feed Water Electrolysis (SFWE)
Urine Recovery	Vapor Compression Distillation (VCD)
Water Processing	Multifiltration (MF)

Exhibit F-1. ECLSS Baseline Technologies for the EMCC Configuration

The rack-level interface requirements were identified for the SFWE and SPE ECLSS technologies from information found in the Interface Technologies Database and the ECLSS Technology Demonstrator Program (TDP) documentation. Exhibit F-2 summarizes the basic rack-level requirements for the fluid and electrical interfaces, respectively, and presents a comparison between the related interface for each technology. The information shown in this exhibit provides a good understanding of the interface commonalties of these two ECLSS technologies.

In reference to the information shown in Exhibit F-2, the number of required "hooks and scars" and interface issues were considered minimal due to the interface compatibilities between baseline and the alternate technology. In fact, the types and number of SFWE and SPE fluid interface input and outputs are the same, with the exception of additional liquid coolant and primary power connections required by the SFWE system. As shown in this exhibit, almost all of the fluid interface connections are identical, with the exception of some of the operation requirement for the lines and connectors. These exceptions can be planned for in the ECLSS evolution by selection of lines and connectors with operational parameters high enough to meet both technologies interface requirements. Electrical interface requirements for both SFWE and SPE technologies can be met by designing the electrical rack-level interfaces to meet the maximum power distribution requirements of both technologies. Due to the commonalties between the electrical input configuration of the two systems, this would require retaining the RS232C cables, and replacement and removal some of the DC power cables when the SFWE technology is replaced with the SPE technology.

ELECTRICAL INTERFACES	TECHNOLOGY			
	SFWE (Baseline)		SPE (Candidate Replacement)	
	Requirement	Connector	Requirement	Connector
Primary Power	28 VDC (30A)	TBD	28 VDC	MS27497E12F4PN (Plug)
Primary 60Hz Power	115 VAC (60Hz, 1Ø, 10A)	TBD	115 VAC (60Hz, 3Ø)	MS27497E14F5PN (Plug)
Primary 400Hz Power	115/208 VAC (400Hz, 3Ø, 25A)	TBD		
CCDS Communication	RS232C Protocol	TBD	RS232C Protocol	MS27497E10F35SN (Socket)

	FLUID INTERFACES (Liquid & Gas)	PRESSURE (psia)		TEMPERATURE		FLOW (lb/day)		Fitting Type	Fitting Size (in.)
		Nominal	Range	Nominal	Range	Nominal	Range		
INPUTS	H_2O Feed	32	30-35	70	60-80	12.78		O-Ring Seal	1/4
		35	35-40	Ambient	60-120	12.48	.216-16.56	Compression	1/4
	N_2 Supply (O_2 Side)	182	180-185	70	60-80	0.076	0.076	O-Ring Seal	1/4
	(H_2 Side)	182	180-185	70	60-80	included ↑	included ↑	O-Ring Seal	1/4
	(O_2 & H_2)	265	260-270	Ambient	Ambient-100	* 67 in^3	* 67 in^3	Compression	1/4
OUTPUTS	O_2 Product	20	14.5-25	70	60-85	11.12		O-Ring Seal	1/4
		20	Ambient-230	120	Ambient-130	11.04	.192-14.64	O-Ring Seal	1/2
	H_2 Product	20	14.5-25	70	60-85	1.39		O-Ring Seal	1/4
		25	Ambient-195	120	Ambient-130	1.39	.024-1.85	O-Ring Seal	1/4
	O_2 Vent	14.7	0-20	80	70-95			O-Ring Seal	1/4
		Ambient	Ambient-230	120	Ambient-130	* 8.5 in^3	* 8.5 in^3	O-Ring Seal	1/2
	H_2 Vent	14.7	0-20	80	70-95			O-Ring Seal	1/4
		Ambient	Ambient-195	120	Ambient-130	* 73 in^3	* 73 in^3	O-Ring Seal	1/4
	Liquid Coolant	25	14.5-30	44	42-46	12k	9.6k-14.4k		

* @ Start-Up

BASELINE TECHNOLOGY
Static Feed Water Electrolysis (SFWE)

CANDIDATE REPLACEMENT TECHNOLOGY
Solid Polymer Electrolysis (SPE)

Exhibit F-2. Comparison of Fluid and Electrical Interfaces for SFWE and SPE Technologies

In order to reduce the required number of "hooks and scars", the temperature and pressure requirements for each fluid interface should exceed the highest value of the two technologies by a predefined safety factor. The initial designed input pressure for the H_2O and N_2 supply should be based on the higher SPE technology requirements and then regulated down to the required pressure for the baseline SFWE technology. This will provide for easier deregulation on the supply pressures and connection of the interfaces between the baseline and replacement technologies. The SFWE technology requires two N_2 supply lines, one for the O_2 side and the other for the H_2 side, while the SPE technology requires only one N_2 supply line. This would require that one of the N_2 supply lines be plugged when the SFWE is replaced by the SPE. Also, the H_2O and N_2 system interface connector types are different and require either a transition connector be used between the rack interface line and the SPE system or that the rack interface line be replaced with a line containing a 1/4" compression fitting at one end, instead of the 1/4" o-ring seal fitting used with the SFWE system. Considerations should be given to the 1/2" O_2 product and vent lines and connectors to determine if 1/4" lines and connectors could be utilized, providing a small reduction in the "hooks and scars" requirements. The liquid coolant interfaces required for the SFWE system is not required for the SPE system and should be removed, due to the fact that the SPE system utilizes cabin air, which is blown through the system to dissipate heat generated by the system, and requires no interfaces.

As mentioned above, the electrical interface requirements for both SFWE and SPE technologies can be met by designing the electrical rack-level interfaces to meet the maximum power distribution requirements of both technologies. The types of electrical interface connectors were not specified for the SFWE system and, therefore, could use the same type of interface connectors used by the SPE system. This can be accomplished by using the same connectors but with only the required pin configuration for each electrical interface for the given technology. Both technologies require basically the same primary 28 VDC interfaces. The 115 VAC power requirements will be changed to 28 VDC for the final flight version of each technology. When the SFWE system is replaced with the SPE system, a DC power cable should be removed and its connectors, on the rack interface plate, should be plugged to guard against any shorting. The SFWE system's RS232C rack interface connection requires only three of the normal RS232 data lines, where the SPE system requires seven of the data lines for Command, Control, and Display Subsystem (CCDS). Since both technologies use the same data line configuration, RS232C protocol, the same cable can be used for CCDS communications for both technology systems.

In addition to these "hooks and scars" issues, a related issue is the heat load penalties for both technologies on the Space Station. The SFWE system dissipates 648 BTU/HR to the cabin air heat exchanger and 737 BTU/HR to the station's cold plate heat exchanger, while the SPE system dissipates 1307 BTU/HR from the electrolysis assembly and 3901 BTU/HR from the electrolysis cell stack DC power to the cabin air heat exchanger. The SPE technology shows definite heat load penalties placed on the Space Station.

The EMCC AR baseline technology for O_2 generation, SFWE, and one of its alternative replacement technologies, SPE,was found to provide many interchangeable fluid and electrical rack-level interface, due to the related technologies interface commonalties. With a minimal number of rack-level "hooks and scars" identified, the SFWE technology could be replaced with the SPE technology. A summary of the rack-level interface "hooks and scars" for the replacement of the SFWE technology with the SPE technology is shown in Exhibit F-3. In addition , one issue that should be considered is the heat load penalty placed on the Space Station by this ECLSS technology evolution.

- Provide a 1/2" to 1/4" Reduction Line for the O2 Product and Vent Outputs
- Provide an O-Ring Fitting to Compression Fitting Transition line for H2O and N2 Supply Rack Interfaces for the SPE Technology
- All Fluid Interface Lines and Connectors Should Accommodate the Higher Operational Pressure and Temperature Requirements of the SPE Technology.
- Provide Plugs for the Rack Interface Connector for the DC Power Sources and Liquid Coolant sources
- Remove DC power cables and Liquid Coolant lines that are not needed
- Provide a Complete RS232 Rack Connection and Cable Configuration

Exhibit F-3. Rack-Level Interface "Hooks and Scars" Summary for Replacement of SFWE Technology with SPE Technology

The work accomplished under this task included limited analyses which were performed comparing the Solid Polymer Electrolysis O2 generation subsystem with the baseline Static Feed Water Electrolysis Subsystem. The results are examples of the types of "hooks and scars" required to accommodate the alternative technologies. For some alternative technologies relatively minor accommodations will allow the flexibility to incorporate them. Additional data on the other technologies is scarce and more time is required to gather this data. The procedures for performing a cost/benefit analysis has been developed but no results are available. This analysis depends on additional data on the technologies which is scarce and more time is required to gather this data. Appendix F is a full report of the work done under this task.